A Novel Criterion for Determination of the Process Bus Structure to Connect Primary Equipment to the Automation System Based on IEC 61850

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Abstract— **In substation automation system, the appropriate operation of protection, control and monitoring systems depends on connection network accuracy. One of the important topics in modern automation system is connection of primary equipment to automation system by serial network; this connection is named 'process bus'. Generally the configuration of communication network is based on the required data, reliability and commissioning requirements during the installation of the automation system. It is clear that the reliability and security of the communication networks are different respect to their importance. Therefore, the significance of the substation can be used as a criterion to determine bus configuration. In this paper, some significance indices are introduced for determination significance level of substations, and then communication structures of the process bus are determined.**

Key words: **Substation automation system, IEC 61850, Process bus, Primary equipment**

I. Introduction

In conventional automation systems, copper conductors are used to connect primary equipment to the secondary system. Nowadays, by applying of IEC 61850 standard, serial communication networks replaced conventional wiring according to IEC 61850-9-1. In this method, all data are transferred from process to SAS (substation automation system) by serial communication network and appropriate digital switchgear according to IEC 62271 and remote I/Os, sensors and actuators in process level. Fig. 1 shows the conventional connections of the process equipment to SAS by copper wiring. The novel method of the process connection with serial communication has been shown in fig. 2. For determination of the communication network structure between primary equipment and automation system (process bus), the performance of the appropriate operation of SAS should be paid attention. Also, the operation requirements of the network depend on the significance of substation in power system.

In this paper, a criterion is introduced to determine the significance level of transmission and sub-transmission substations. Then, the configuration of the process bus will be explained based on the proposed method.

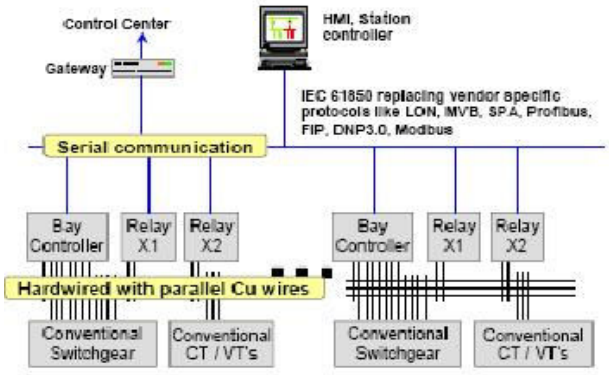

Fig 1: Conventional process connection

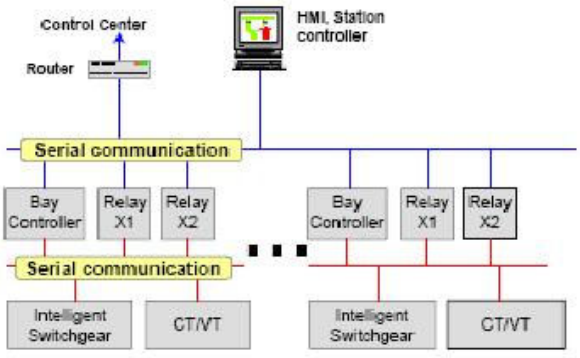

Fig 2: Process connection with serial communication

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II. THE SIGNIFICANCE INDICES OF SUBSTATION

Several factors should be considered to determine the significance level of substation. In this paper, seven factors are introduced as significance indices as follows:

- The substation capacity equals to total capacities of transformers or bus bars
- Quantity of power transformers
- Type of the substation bus bar arrangement including multi circuit breakers, main & transfer bus, double, ring, simple bus bar and etc.
- Quantity of 63kV (or higher) incoming/outgoing feeders
- Location of substation in power network (i.e. radial or ring)
- The significance of the substations depends on its position and loads in the power network. Therefore**,** substations can be classified as follows:
    - Very important substations: This group includes substations that should not be disconnected from the network even for a short time. Disconnection of these substations result in instability, black out or regional blackout.
    - Important substations: This group includes substations that could be disconnected for some minutes. The permanent disconnection of these substations adversely affect on the network. The consumption loads of these substations are high.
    - Normal substations: This group includes substations that could be disconnected for several hours. The consumption loads of these substations are low.
- The significance of the operation functions is different based on bus bar types and other problems; therefore**,** this topic is important for determination significance level of the substations.

III. THE EVALUATION CRITERIA FOR SIGNIFICANCE INDICES

In this paper, evaluation criteria are proposed for each index according to the tables I and II. In order to analyze these criteria, 21 transmission substations and 31 sub-transmission substations with different configurations and positions have been studied and after modifications, the results were examined on other substations. The indices, and evaluation criteria and the results are shown in tables I and II.

Table I : The evaluation criteria in order to determine significance level of sub-transmission substations

Row	Index	The criteria of the evaluation	Score
1	Substation capacity (MVA)	Sum of S/S capacity ≥ 50	2
		Sum of S/S capacity < 50	1
2	No. of transformer (by attention to development in future)	Sum of transformer No. > 2	2
		Sum of transformer No. ≤ 2	1
		Without transformer	0
3	Type of bus bar in substation	Multi circuit breakers	2
		Double/Ring/M & T	1
		Simple	0
4	No. of I/O feeders grater than 63kV or equal to 63kV (by attention to development in future)	No. > 10	2
		2 < No. ≤ 10	1
		No. ≤ 2	0
5	Location of substation in power network	Ring	2
		radial	1
6	The significance of the substation in power network	Very important	0-4
		Important	
		Normal	
7	The significance of operation functions	-	0-4

Table II: The evaluation criteria in order to determine significance level of transmission substations

Row	Index	The criteria of the evaluation	Score
1	Substation capacity (MVA)	Sum of S/S capacity ≥ 500	2
		Sum of S/S capacity < 500	1
2	No. of transformer (by attention to development in future)	Sum of transformer No. > 2	2
		Sum of transformer No. ≤ 2	1
		With out transformer	1.5
3	Type of bus bar in substation	Multi circuit breakers	2
		Double/Ring/M & T	1
		Simple	0
4	No. of I/O feeders grater than 63kV or equal to 63kV (by attention to development in future)	No. > 10	2
		4 < No. ≤ 10	1
		No. ≤ 4	0
5	Location of substation in power network	Ring	2
		radial	1
6	The significance of the substation in power network	Very important	0-4
		Important	
		Normal	
7	The significance of operation functions	-	0-4

IV. THE DETERMINATION AND DECISION

After the determination of the evaluation criteria, the sum of scores determines the significance index.

For the sub-transmission substations:

- If the sum of scores is lower than 9 or equals to 9 then the substation will have low significance level and it will enumerate in S1 group.
- If the sum of scores is higher than 9 then the substation will have high significance level and it will enumerate in S2 group.

For the transmission substations:

- If the sum of scores is lower than 9 then the substation will have low significance level and it will enumerate in T1 group.
- If the sum of scores is higher than 9 or equals to 9 then the substation will have high significance level and it will enumerate in T2 group

These results are shown in table III.

Table III: Determination of significance level of substations

Substation type	Sum of scores	Significance level
Sub-transmission	Sum ≤ 9	Low (S1)
	Sum > 9	High (S2)
Transmission	Sum < 9	Low (T1)
	Sum ≥ 9	High (T2)

V. THE DETERMINATION OF THE PROCESS BUS STRUCTURE

In order to obtain appropriate connection configuration, transmission and sub-transmission substations can be classified based on regions. There are many choices respect to executive problems, but in this research the regions are classified based on the bay zones. In this method the substation is divided to the regions considering primary equipment collection that performs common tasks in the bay. After regions classification based on bay zones and the determination of the significance indices, process bus structure must be determined. For this purpose, there are three choices:

Alternative 1: the process bus with separate configuration and routers for each region. In this case, each bay has an independent process bus; in addition, there is a common connection bus that is used by control and protection equipment for data transfer to other regions.

The Data of each region is transferred to common connection bus by the each region-installed routers. This choice is generally applicable for T2 and S2 types.

Alternative 2: the process bus with multiregional configuration is similar to the previous configuration, but it supports several bays. The data is transferred from different regions by the routers. This choice is applicable for different types (S1, S2, T1 and T2).

Alternative 3: the process bus is accomplished with singular connection configuration without router. In this method, a single bus exchanges the data. This configuration does not need the routers but the data traffic increase on buses. This choice is applicable for S1 type.

VI. PROCESS BUS STRUCTURE FOR TWO TYPICAL SUBSTATIONS

The obtained results have been implemented typically on a S1 type sub-transmission substation (see fig. 3 and 4) and a T2 transmission substation (see fig. 5 and 6).

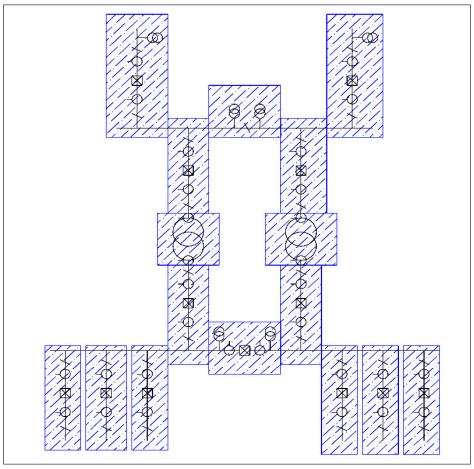

Fig 3: Regions classification based on bay zones in a sub-transmission substation

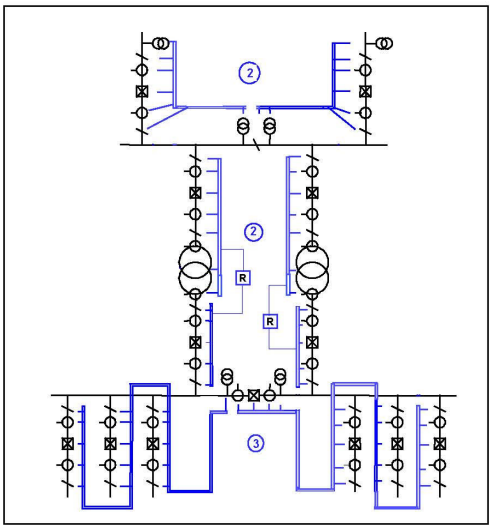

Fig 4: The process bus configuration based on alternative 2 and 3 in a sub-transmission substation (S1)

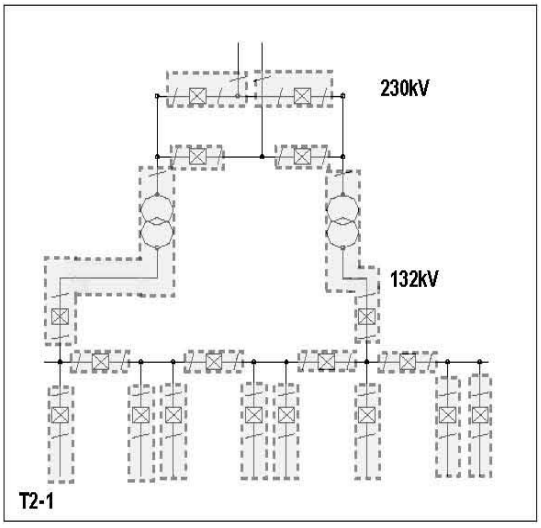

Fig 5: Regions classification based on bay zones in a the transmission substation

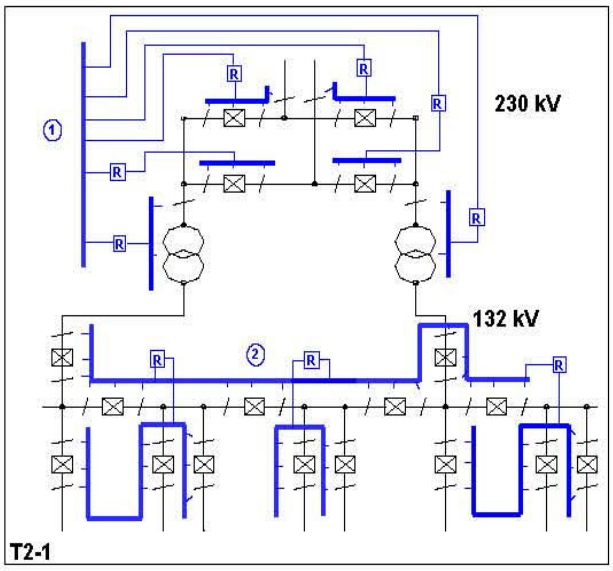

Fig 6: The process bus configuration based on alternative 1and 2 in a transmission substation (T2)

VII. Conclusion

The performance requirements and reliability of the substation are very significant to determine communication system as well as process bus configuration. Also, arrangements, configurations and switchgear designs are other important issues for determination of process bus structure. Designers can select the different methods for the determination of the process bus respect to significance of the substation and commissioning problems. In this paper the process bus structure were presented based on the significance level of substations. The significance level of the substations depends on several factors that named significance indices. These indices consist of substation capacity, number of the transformers, substation configuration, number of feeders, location of substation in power network (ring or radial), and substation importance in power network and operation functions.

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